An Automated Soil Moisture and Temperature Monitoring Program for Wisconsin Glacial Till Soils

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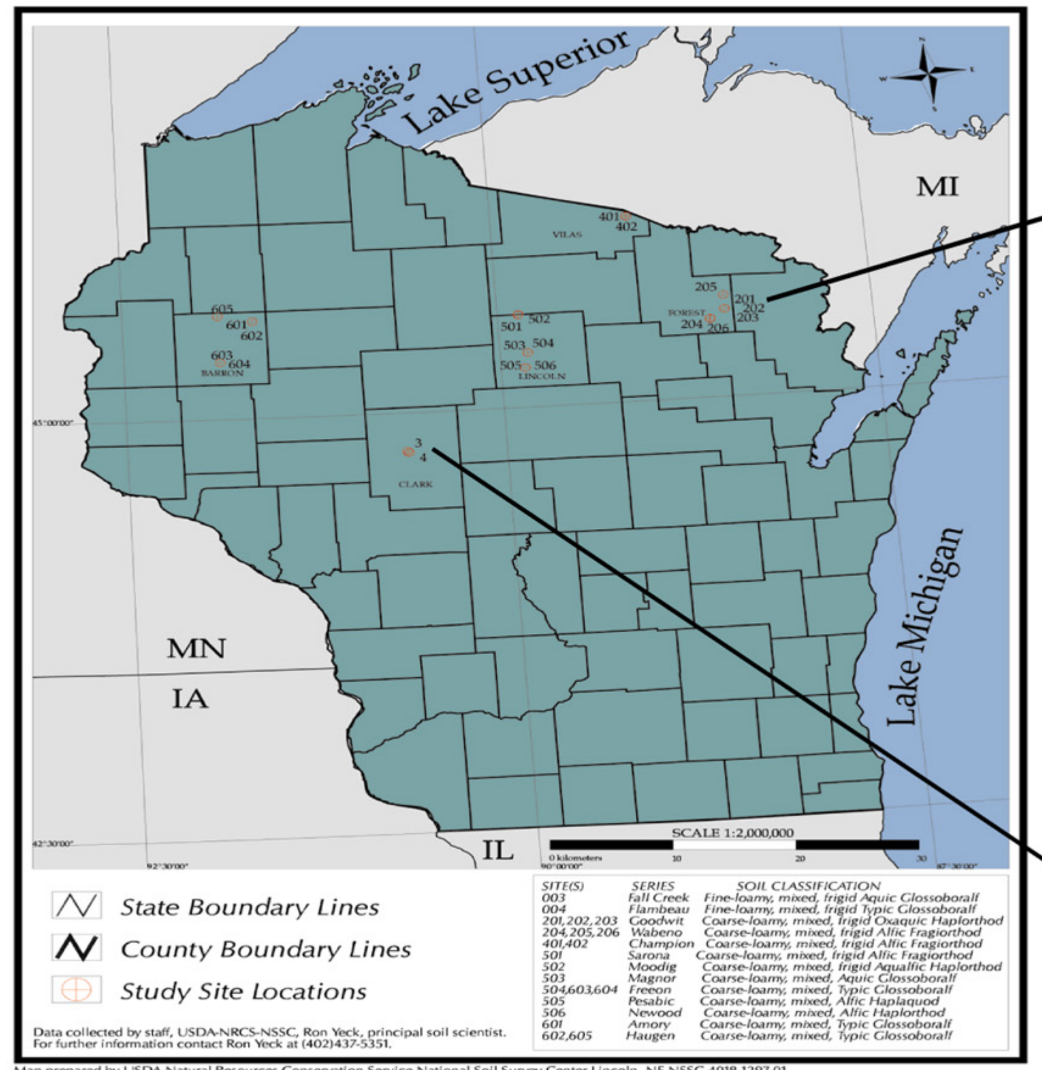
Figure 1. Wisconsin Soil Moisture Study Sites



Map prepared by USDA-Natural Resources Conservation Service National Soil Survey Center Lincoln, NE NSSC-4018-1297-01

Photo 1. Representative Forested "Cradle" and "Knoll" Study Site (site 201)

Photo 2. Cultivated Study Site in Clark County (site 003)

Photo 3. Data Acquisition and Data Retrieval

Introduction

This field monitoring project was developed because clod bulk density measurements did not adequately reflect the dense till jointing that affects water movement and availability in these soils.

The data presented are from study areas in Forest County, Northern Wisconsin (Figure 1). The data are from soils formed in and above dense glacial till on landscapes dominated by tree-tip pit ("cradle") and tree-tip mound ("knoll") microtopography (Photo 1).

The objectives for this paper are:

- To inform other scientists of the Northern Wisconsin soil moisture work and provide opportunity for scientific exchange
- Show the seasonal soil moisture available to plants and the effects of landscape position, microtopography, and dense till horizons on that soil moisture
- Demonstrate that in "cradle" and "knoll" landscapes, generalizations about soil moisture are very complex

Study Methods

The study includes twenty-one sites representing both forest (Photo 1) and cultivated (Photo 2) land uses in several Wisconsin counties (Figure 1). Within these areas, effects of the dense glacial till horizons, and at forested sites the "cradle" and "knoll" microtopography (evident in Photo 1), are important.

Sites are instrumented with resistance type soil moisture and temperature sensors. The moisture sensors are sensitive in a range of about 0.1-bar to about 15-bar soil moisture tensions. At each site, sensors are installed at twelve triplicated depths to 200 cm. At three depths (20, 50, and 200 cm), the sensors contain a thermistor for soil temperature measurements. Sensors are monitored by dataloggers powered by solar-charged batteries (Photos 2 and 3). Each sensor stack is connected to one of three multiplexers. Measurements are taken every twenty minutes and two-hour averages stored from each sensor. Data are retrieved at three-month intervals with palm top computers.

Results And Discussion

Data presented in this paper will focus on representative soil moisture data from Forest County forested sites (204, 205, and 201) at which dense till horizons and the microtopography are thought to strongly influence soil moisture. Monthly soil moisture tensions are presented in Tables 2 to 4 and from associated graphs that depict July monthly maximum, minimum, and average soil moisture tensions (Figures 4 and 6). Ten-day daily periods of soil moisture tension from the same sites are also shown (Figures 5 and 7). One temperature graph (Figure 2) is included.

Northern Wisconsin soils remain near freezing to 25 cm until early April but air temperatures in the datalogger enclosure continued to drop below zero through May in 1997 (Figure 2). Soil moisture remains static while the soil is frozen, but in April soil moisture tension begins to decrease, that is, plant-available moisture increases (Tables 2 to 4[1]).

Table 2 depicts the moisture changes of a typical "knoll" area. The upper boundary of the dense till horizons occurs at 70-100 cm (Figure 3). Soil profile moisture depletion begins to show a pattern in June in horizons down to 100 cm where root concentrations are highest (Figure 3). In August and September, horizons formed in the till become very dry[2]. We attribute this drying to soil moisture movement upward under tension toward overlying horizons where moisture depletion occurs because of high root concentrations. Figure 4 shows maximum, minimum, and average soil moisture tensions for July 1997. Figure 5 shows soil moisture tensions for a ten-day July period during which precipitation was received (Table 1). Below 120 cm, the soil moisture tension was not affected by the precipitation.

Table 3 depicts the moisture changes in a typical "cradle" area. Again, soil moisture tensions increase beginning in June as plant roots extract soil moisture. Because "cradle" areas are formed by tree tips, soil horizons are often disrupted and irregular. In this example, maximum soil moisture tensions in July are near the soil surface with soil moisture tension increases also at 80 and 140 cm (Figures 6 and 7). The drier zone at 80 cm most likely reflects moisture depletion by roots. The drier zone at 140 cm is probably related to soil horizonation since roots are not described at that depth. Figure 7 reflects a soil moisture profile similar to that of Figure 6, but shows responses to precipitation (Table 1).

Although there are generally differences between "cradle" and "knoll" areas as discussed above, some of each area show data that are atypical. Table 4 is such an example where a "knoll" area remains moist even through September in all horizons. This pedon, from site 201 (Figure 1), has "cradle" and "knoll" microtopography but the general topography is relatively flat (Photo 1 shows this area) which may cause the soils to be wetter throughout the year than soils on steeper slopes like those at site 205. However, other "knoll" soils in this area do become very dry. By contrast, examples of "cradle" soils could be given where they dry similar to "knoll" soils. Both the generalities and the anomalies exist largely because of the complex, heterogeneous nature of soils in areas of "tree throw".

Regardless of the microtopography, these soils generally remain very moist in the lower horizons, commonly below 140 cm. There are some exceptions not illustrated in this presentation.

[1] Some change may be attributable to effect of temperature on the resistance sensor.
[2] Maximum values of >15-bars have been used to indicate that the range of the moisture sensors has been exceeded.

Table 1. July 1997 Precipitation, Forest County[1]

Date	Amount (cm)
7/2/97	1.27
7/3/97	0.76
7/7/97	0.25
7/8/97	1.27
7/9/97	0.25
7/13/97	0.76
7/14/97	0.76
7/16/97	1.52
7/25/97	0.25

[1] Near site 205.

Figure 2. Air and Soil Temperatures, Site 205 (Wabeno)

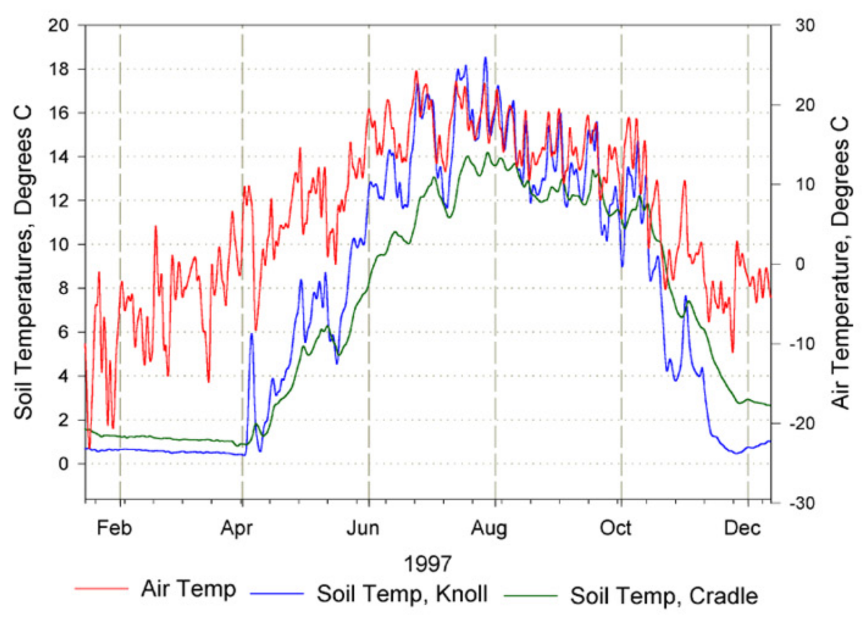


Figure 3. Depiction of "Cradle" and "Knoll" Soil Profiles

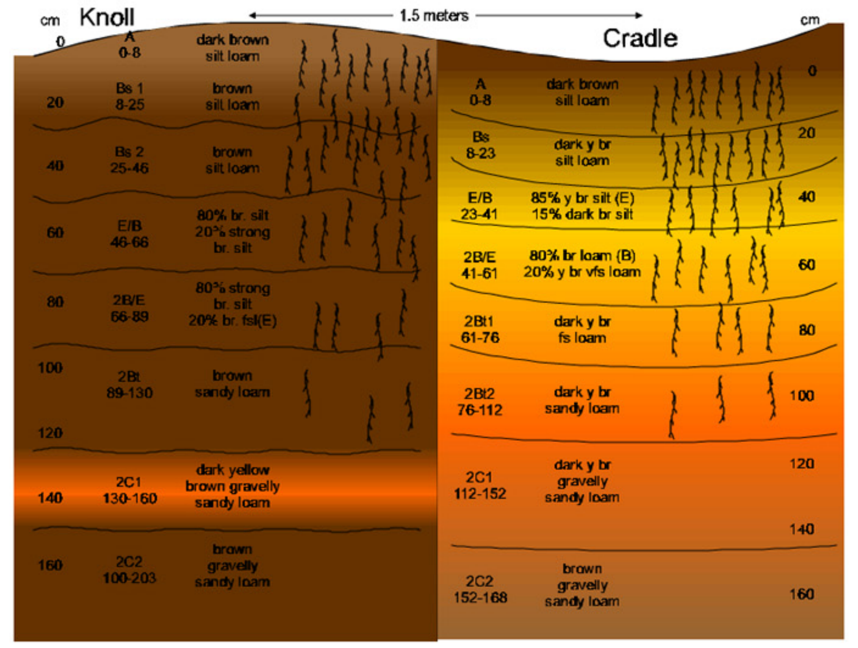


Table 2. Typical "Knoll" Soil Moisture Pattern (Bars of Tension)

Depth	Jan-97	Feb-97	Mar-97	Apr-97	May-97	Jun-97	Jul-97	Aug-97	Sep-97
10cm	0.42	0.41	0.35	0.34	0.32	0.45	0.89	1.41	0.97
25cm	0.35	0.34	0.33	0.28	0.27	0.32	0.65	1.01	0.70
40cm	0.38	0.39	0.36	0.33	0.32	0.40	1.07	1.77	1.15
50cm	0.42	0.43	0.42	0.38	0.36	0.43	1.55	4.44	2.87
70cm	0.46	0.47	0.46	0.39	0.38	0.45	2.28	10.58	8.95
80cm	0.73	0.76	0.75	0.71	0.68	0.74	>15	>15	>15
100cm	0.55	0.56	0.56	0.52	0.50	0.49	11.30	>15	>15
120cm	0.51	0.52	0.54	0.53	0.52	0.49	0.51	>15	>15
140cm	0.55	0.57	0.58	0.56	0.54	0.51	0.51	>15	>15
160cm	0.46	0.47	0.48	0.49	0.48	0.46	0.50	>15	>15
180cm	0.38	0.38	0.38	0.35	0.35	0.35	0.37	4.19	>15
200cm	0.22	0.22	0.21	0.16	0.16	0.16	0.17	0.30	0.62

Data from site 205. July data is shown in Figure 4.

Figure 4. Knoll Area Soil Moisture Tensions, July 1997 (from Table 2)

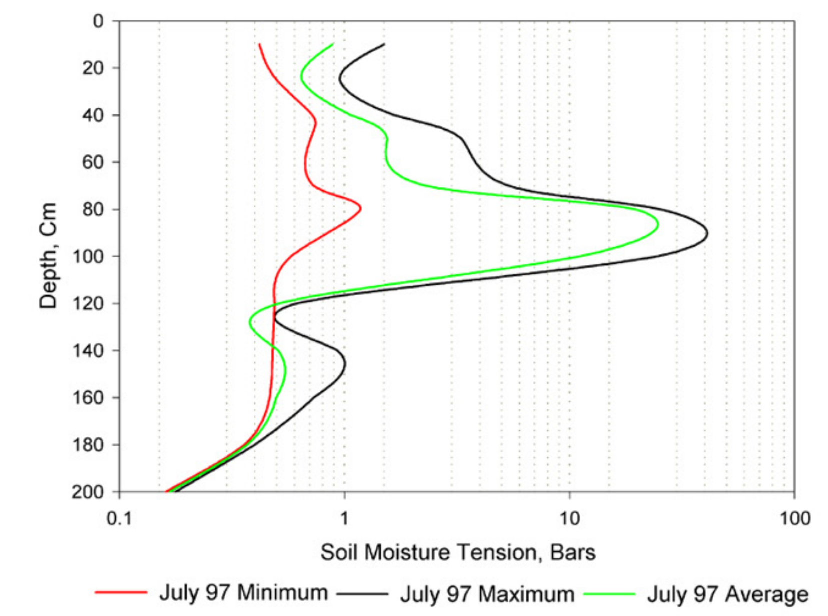


Figure 5. Knoll Area Soil Moisture Tension Change (10-day period)

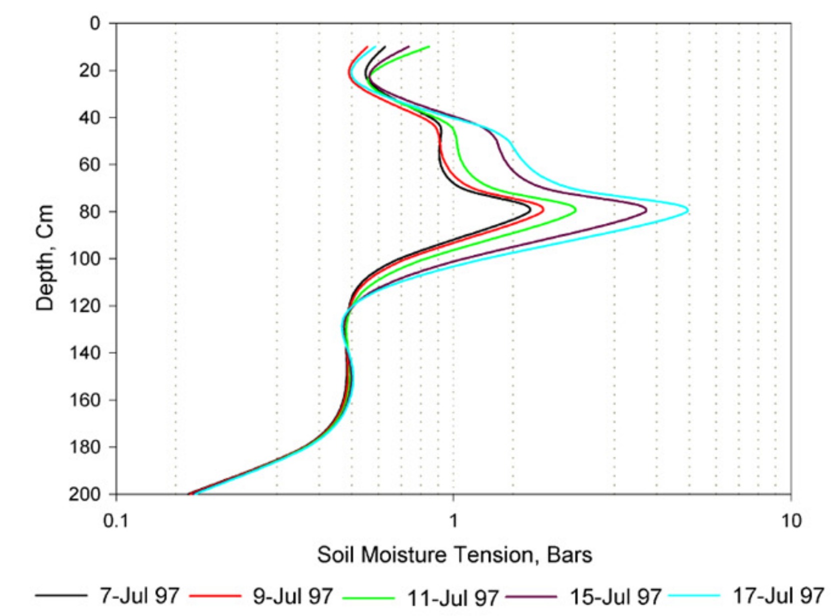


Table 3. Typical "Cradle" Soil Moisture Pattern (Bars of Tension)

Depth	Jan-97	Feb-97	Mar-97	Apr-97	May-97	Jun-97	Jul-97	Aug-97	Sep-97
10cm	0.40	0.39	0.39	0.36	0.28	1.82	5.58	>15	4.93
25cm	0.42	0.27	0.21	0.22	0.20	0.45	2.38	3.68	1.94
40cm	0.33	0.33	0.31	0.25	0.28	0.53	2.41	4.55	2.00
50cm	0.25	0.24	0.21	0.14	0.17	0.33	0.95	2.89	2.03
70cm	0.38	0.38	0.36	0.27	0.27	0.39	0.82	2.04	1.80
80cm	0.84	0.86	0.85	0.74	0.69	0.69	0.86	1.25	1.36
100cm	0.15	0.17	0.10	0.09	0.09	0.11	0.22	0.32	0.38
120cm	0.19	0.20	0.19	0.15	0.15	0.15	0.17	0.21	0.24
140cm	0.23	0.24	0.24	0.15	0.20	0.20	0.20	0.21	0.23
160cm	0.12	0.13	0.13	0.11	0.10	0.10	0.10	0.09	0.09
180cm	0.19	0.19	0.20	0.14	0.16	0.16	0.16	0.18	0.19
200cm	0.17	0.18	0.18	0.06	0.11	0.12	0.16	0.17	0.18

Data from site 205. July data is shown in Figure 6.

Figure 6. Cradle Area Soil Moisture Tensions, July 1997 (from Table 3)

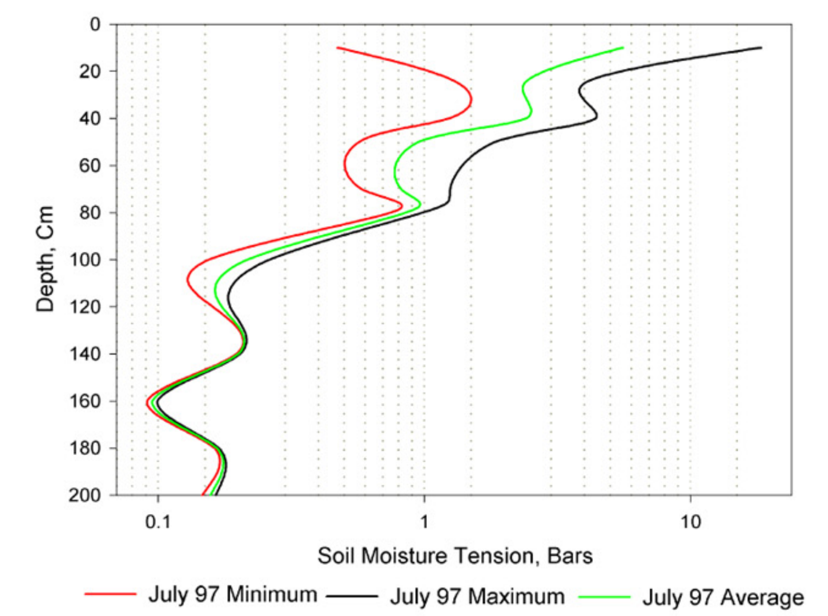


Figure 7. Cradle Area Soil Moisture Tension Change (10-day period)

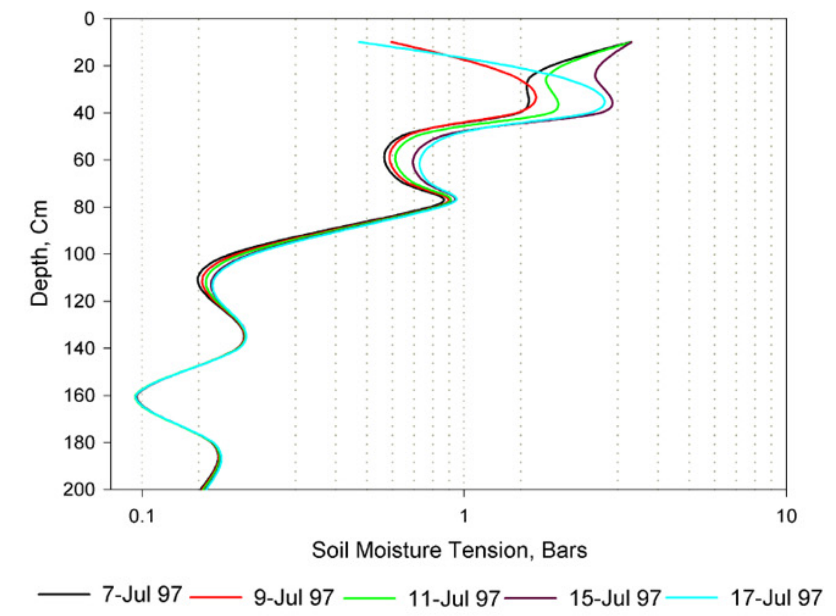


Table 4. An Atypical "Knoll" Soil Moisture Pattern (Bars of Tension)

Depth	Jan-97	Feb-97	Mar-97	Apr-97	May-97	Jun-97	Jul-97	Aug-97	Sep-97
10cm	0.31	0.30	0.29	0.19	0.19	0.21	0.29	0.41	0.27
25cm	0.30	0.30	0.29	0.20	0.19	0.20	0.28	0.38	0.26
40cm	0.30	0.30	0.29	0.18	0.19	0.20	0.29	0.41	0.28
50cm	0.38	0.39	0.38	0.16	0.19	0.26	0.44	0.67	0.43
70cm	0.48	0.48	0.44	0.20	0.19	0.29	0.53	0.85	0.47
80cm	0.58	0.57	0.49	0.21	0.18	0.26	0.48	0.81	0.46
100cm	0.39	0.39	0.36	0.21	0.19	0.24	0.42	0.64	0.35
120cm	0.31	0.27	0.27	0.14	0.14	0.15	0.31	0.53	0.51
140cm	0.48	0.49	0.49	0.37	0.33	0.28	0.39	0.64	0.64
160cm	0.32	0.32	0.29	0.14	0.13	0.13	0.29	0.44	0.45
180cm	0.08	0.08	0.09	0.09	0.09	0.08	0.08	0.16	0.18
200cm	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.15	0.20

Data from site 201.

Conclusions

- "Cradle" soil areas are generally more moist than "knoll" soil areas in the project soils, although the "tree throw" process that causes "cradles" and "knolls" produces such soil horizon heterogeneity that consistent prediction of soil moisture within these areas is imperfect.
- Soil horizons below the major rooting depths become dry in August and September, probably by upward soil moisture movement under tension toward the overlying horizons where root uptake of soil moisture is more active.
- At the 200 cm depth, and usually below about 140 cm, most project soils remain at field capacity (0.33 bar) or wetter throughout the year.
- Soil moisture patterns are very complex in "cradle" and "knoll" areas, and would render the interpretation of remotely sensed soil moisture in those areas very difficult.
- Soil temperatures begin to increase in early April after the winter quiescence with subsequent soil moisture tension changes marking the beginning of plant growth and soil moisture dynamics for the year.

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Soil Temperature and Moisture Team